Chemical Reactions

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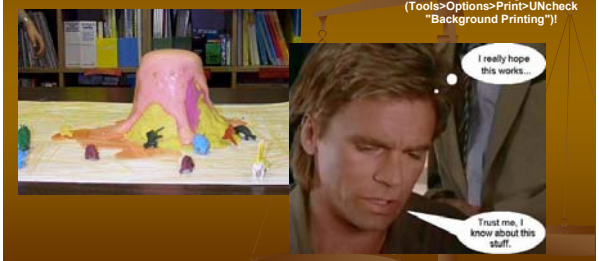


Types of Reactions

- There are five types of chemical reactions we will talk about:
  1. Synthesis reactions
  2. _____ reactions
  3. Single displacement reactions
  4. _____ reactions
  5. Combustion reactions
- You need to be able to identify the type of reaction and predict the product(s)

Steps to Writing Reactions

- Some steps for doing reactions
  1. Identify the type of reaction
  2. Predict the product(s) using the type of reaction as a model
  3. Balance it

Don't forget about the diatomic elements! (BrINClHOF) For example, Oxygen is O_2 as an element.

In a compound, it can't be a diatomic element because it's not an element anymore, it's a compound!

How to Describe a Reaction

- **A reaction can be described several ways:**

#1. In a sentence every item is a word

Copper reacts with chlorine to form copper (II) chloride.

#2. In a word equation some symbols used

Copper + chlorine → copper (II) chloride

#3. In a chemical equation only chemical equations are used

$Cu + Cl_2 \rightarrow CuCl_2$

Symbols in Equations

- (s) after the formula = solid: $Fe_{(s)}$
- (g) after the formula = gas: $CO_{2(g)}$
- (l) after the formula = liquid: $H_2O_{(l)}$
- **(aq) after the formula = dissolved in water, an aqueous solution: $NaCl_{(aq)}$ is a salt water solution**

Symbols used in equations

- the arrow → separates the reactants from the products (arrow points to products)
  - Read as: "reacts to form" or yields
- The plus sign + means "and"
- **↑ used after a product indicates a gas has been *produced*: $H_2\uparrow$**
- **↓ used after a product indicates a solid has been *produced*: $PbI_2\downarrow$**

Symbols used in equations

- $\rightleftharpoons$ double arrow indicates a reversible reaction (more later)
- $\xrightarrow{\Delta}$, $\xrightarrow{\text{heat}}$ shows that heat is supplied to the reaction
- $\xrightarrow{Pt}$ is used to indicate a catalyst is supplied **(in this case, platinum is the catalyst)**

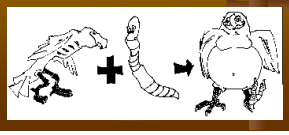
Write a skeleton equation for:

1. **Solid iron (III) sulfide reacts with gaseous hydrogen chloride to form iron (III) chloride and hydrogen sulfide gas.**
2. **Nitric acid dissolved in water reacts with solid sodium carbonate to form liquid water and carbon dioxide gas and sodium nitrate dissolved in water.**

1. Synthesis reactions

- **Synthesis reactions** occur when two substances (generally **elements**) combine and form a compound. (Sometimes these are called combination or addition reactions.)

  reactant + reactant → 1 product
- Basically: A + B → AB
  - Example: $2H_2 + O_2 \rightarrow 2H_2O$
  - Example: $C + O_2 \rightarrow CO_2$



Write a skeleton equation for:

1. **Solid iron (III) sulfide reacts with gaseous hydrogen chloride to form iron (III) chloride and hydrogen sulfide gas.**

   $FeS_{(s)} + HCl_{(g)} \rightarrow FeCl_{2(s)} + H_2S_{(g)}$
2. **Nitric acid dissolved in water reacts with solid sodium carbonate to form liquid water and carbon dioxide gas and sodium nitrate dissolved in water.**

   $HNO_{3(aq)} + Na_2CO_{3(g)} \rightarrow CO_{2(g)} + H_2O_{(l)}$

Now, read these equations:

$Fe_{(s)} + O_{2(g)} \rightarrow Fe_2O_{3(s)}$

$Cu_{(s)} + AgNO_{3(aq)} \rightarrow Ag_{(s)} + Cu(NO_3)_{2(aq)}$

$NO_{2(g)} \xrightarrow{Pt} N_{2(g)} + O_{2(g)}$

Balanced Chemical Equations

- **According to the Law of Conservation of Mass: atoms aren't created or destroyed in a chemical reaction, they are just rearranged.**
- **All the atoms we *start with* in the reactants we must *end up with* in the products *(meaning: balanced!)***
- **A balanced equation has the same number of each element *on both sides* of the equation.**

Rules for balancing:

1) **Assemble the correct formulas for all the reactants and products, using "+" and "→"**
2) **Count the number of atoms of each type appearing on both sides**
3) **Balance the elements *one at a time* by adding *coefficients* (the numbers in front) where you need more - save balancing the H and O until LAST!**

   (hint: I prefer to save O until the *very* last)
4) **Double-Check to make sure it is balanced.**

Never

- **Never change a subscript to balance an equation (You can only change coefficients)**
  - **If you change the subscript (formula) you are describing a different chemical.**
  - **H_2O is a different compound than H_2O_2**
- **Never put a coefficient in the *middle* of a formula; they must go only in the front**

  2NaCl is okay, but Na2Cl is not.

Practice Balancing Examples

- $\_AgNO_3 + \_Cu \rightarrow \_Cu(NO_3)_2 + \_Ag$
- $\_Mg + \_N_2 \rightarrow \_Mg_3N_2$
- $\_P + \_O_2 \rightarrow \_P_4O_{10}$
- $\_Na + \_H_2O \rightarrow \_H_2 + \_NaOH$
- $\_CH_4 + \_O_2 \rightarrow \_CO_2 + \_H_2O$

Practice Balancing Examples

- $2AgNO_3 + \_Cu \rightarrow \_Cu(NO_3)_2 + 2Ag$
- $3Mg + \_N_2 \rightarrow \_Mg_3N_2$
- $4P + 5O_2 \rightarrow \_P_4O_{10}$
- $2Na + 2H_2O \rightarrow \_H_2 + 2NaOH$
- $\_CH_4 + 2O_2 \ \_CO_2 + 2H_2O$

Types of Reactions

- **There are probably millions of reactions.**
- **We can't remember them all, but luckily they will fall into several categories.**
- **We will learn: a) the 5 major types.**
- **We will be able to: b) predict the products.**
- **For some, we will be able to: c) predict whether or not they will *happen at all.***

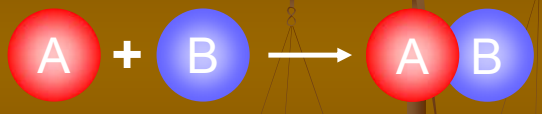
The Skeleton Equation

- **All chemical equations are a *description* of the reaction.**
- **A skeleton equation uses formulas and symbols to describe a reaction**
  - **but doesn't indicate how many; this means they are NOT balanced**

Synthesis Reaction

also called Combination Reactions

2 substances combine to make one compound



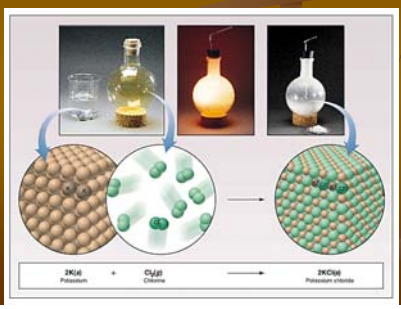
The general equation is A + B → AB

Synthesis Reaction

$HCl_{(g)} + NH_{3(g)} \rightarrow NH_4Cl_{(s)}$

Synthesis Reactions

- Here is another example of a synthesis reaction



Practice

- Predict the products. Write and balance the following synthesis reaction equations.
- Sodium metal reacts with chlorine gas

  $Na_{(s)} + Cl_{2(g)} \rightarrow$
- Solid Magnesium reacts with fluorine gas

  $Mg_{(s)} + F_{2(g)} \rightarrow$
- Aluminum metal reacts with fluorine gas

  $Al_{(s)} + F_{2(g)} \rightarrow$

#1 Synthesis Reactions

also called Combination Reactions

- **2 substances combine to make one compound**
- **the general equation is : A + B → AB**
  - **$Ca + O_2 \rightarrow CaO$** element + element
  - **$SO_2 + O_2 \rightarrow SO_3$** compound + element
  - **$CO_2 + H_2O \rightarrow H_2CO_3$** compound + compound
- **We can predict the products, especially if the *reactants are two elements*.**
- **$Mg + N_2 \rightarrow$ Mg_3N_2**

Complete and balance:

- **$Ca + Cl_2 \rightarrow$**
- **$Fe + O_2 \rightarrow$ (assume iron (II) oxide is the product)**
- **$Al + O_2 \rightarrow$**
- **Remember that the first step is to write the *correct formulas* – you can still change the *subscripts* at this point, but not later while balancing!**
- **Then balance by changing the coefficients only**

#2 Decomposition Reaction

The general equation is : AB → A + B

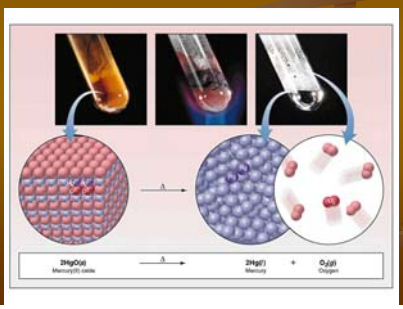
A reaction where a more complex molecule breaks down to form two or more simpler products

Decomposition Reactions

- **Decomposition reactions** occur when a compound breaks up into the elements or in a few to simpler compounds
- **1 Reactant → Product + Product**
- In general: AB → A + B
- Example: 2 H_2O → 2H_2 + O_2
- Example: 2 HgO → 2Hg + O_2

Decomposition Reactions

- Another view of a decomposition reaction:



Decomposition Reaction

$2NH_4NO_{3(s)}$ → $4H_2O_{(g)}$ + $2N_{2(g)}$ + $O_{2(g)}$ + energy

Timothy McVeigh bombing, 1995

Regular building demolition with ammonium nitrate explosives

Decomposition Reactions

- **We can predict the products if it is a binary compound (which means it is made up of only two elements)**
  - **It breaks apart into the elements:**
- **H_2O** —electricity→
- **HgO** —Δ→

mercury (II) oxide
cinnabar

Decomposition Exceptions

- Carbonates and chlorates are special case decomposition reactions that do not go to the elements.
  - Carbonates (CO_3^{2-}) decompose to carbon dioxide and a metal oxide
    - Example: $CaCO_3$ → CO_2 + CaO
  - Chlorates (ClO_3^-) decompose to oxygen gas and a metal chloride
    - Example: 2 $Al(ClO_3)_3$ → 2 $AlCl_3$ + 9 O_2

Practice

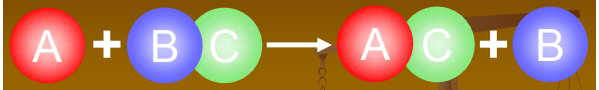
- Predict the products. Then, write and balance the following decomposition reaction equations:
- Solid Lead (IV) oxide decomposes
  $PbO_{2(s)} \rightarrow$
- Aluminum nitride decomposes
  $AlN_{(s)} \rightarrow$

Decomposition Reactions

- *one reactant* breaks apart into two or more elements or compounds.
- the general equation is : AB → A + B
- $H_2O \xrightarrow{\text{electricity}} H_2 + O_2$
- $CaCO_3 \xrightarrow{\Delta} CaO + CO_2$
- $CuSO_4 \cdot 5H_2O \xrightarrow{\Delta} CuSO_4 + 5H_2O$

- $2NaHCO_{3(s)} \xrightarrow{\Delta} Na_2CO_{3(s)} + H_2O_{(l)} + CO_{2(g)}$
- Note that *energy* (heat, sunlight, electricity, etc.) is usually required

Single Displacement Reaction (Replacement)

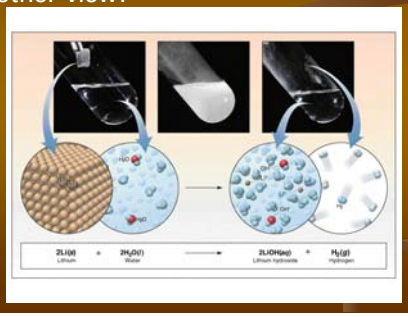


A reaction where an element displaces another element in a compound, producing a new compound and an element

- **A metal will replace a cation (metal or H)**
- **A non-metal will replace an anion (non-metal)**

Single Replacement Reactions

- Another view:



Single Replacement Reactions

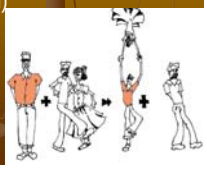
- **Single Replacement Reactions** occur when one element replaces another in a compound.
- A metal can replace a metal (+) **OR** a nonmetal can replace a nonmetal (-).
- **element + compound→ element + compound**

  A + BC → AC + B (if A is a metal) **OR**

  A + BC → BA + C (if A is a nonmetal)

  (remember the cation always goes first!)

When H_2O splits into ions, it splits into H^+ and OH^- (not H+ and O^{-2} !!)



Single Replacement Reactions

- $Zn_{(s)} + 2\ HCl_{(aq)} \rightarrow ZnCl_{2\ (aq)} + H_{2\ (g)}$
- zinc metal and hydrochloric acid react to form zinc chloride and hydrogen gas in this single-displacement reaction.

Single Replacement Reactions

- One element replaces another
- the reaction follows the form of: compound + element → compound + element
- Reactants must be *an element and a compound.*
- Products will be a different element and a different compound.

- $Na + KCl \rightarrow K + NaCl$ (cations switched)
- $F_2 + LiCl \rightarrow LiF + Cl_2$ (anions switched)

Single Replacement Reactions

- Sodium chloride solid reacts with fluorine gas

$2\ NaCl_{(s)} + F_{2(g)} \rightarrow 2\ NaF_{(s)} + Cl_{2(g)}$

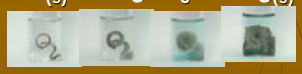
Note that fluorine replaces chlorine in the compound

- Aluminum metal reacts with aqueous copper (II) nitrate

$Al_{(s)} + Cu(NO_3)_{2(aq)} \rightarrow$

Single Replacement Reactions

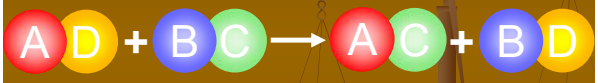
- **Metals will replace other metals (and they can also replace hydrogen)**
- **$Zn_{(s)} + 2\ HCl_{(aq)} \rightarrow ZnCl_{2\ (aq)} + H_{2\ (g)}$**
- **$Cu_{(s)} + 2AgNO_3 \rightarrow 2Ag_{(s)} + Cu(NO_3)_2$**



- **Think of water as: HOH**
  - **Metals replace the first H, and then combines with the hydroxide (OH).**
- **$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2\ NaOH_{(aq)} + H_{2(g)}$**

#4 Double Displacement Reaction

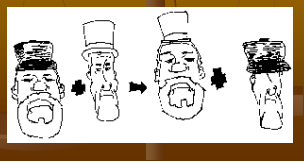
AD + BC → AC + BD



Two compounds switch parts to make two new compounds
the general equation is : AB + CD → AD + CB

Double Replacement Reactions

- **Double Replacement Reactions** occur when a metal replaces a metal in a compound and a nonmetal replaces a nonmetal in a compound
- **Compound + compound → compound + compound**
- AB + CD → AD + CB



Double Replacement Reactions

- Think about it like "foil"ing in algebra, first and last ions go together + inside ions go together
- Example:

$AgNO_{3(aq)} + NaCl_{(s)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$

- Another example:

$K_2SO_{4(aq)} + Ba(NO_3)_{2(aq)} \rightarrow 2KNO_{3(aq)} + BaSO_{4(s)}$

Complete and balance:

- **assume all of the following reactions actually take place:**

$CaCl_2 + NaOH \rightarrow$

$CuCl_2 + K_2S \rightarrow$

$KOH + Fe(NO_3)_3 \rightarrow$

$(NH_4)_2SO_4 + BaF_2 \rightarrow$

$NaOH_{(aq)} + HCl_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$

How to recognize which type?

- Look at the reactants:

E + E OR C + C = Synthesis

C = Decomposition

E + C = Single displacement

C + C = Double displacement

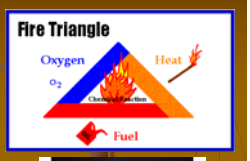
Practice

- Predict the products. Balance the equation

1. $HCl_{(aq)} + AgNO_{3(aq)} \rightarrow$
2. $CaCl_{2(aq)} + Na_3PO_{4(aq)} \rightarrow$
3. $Pb(NO_3)_{2(aq)} + BaCl_{2(aq)} \rightarrow$
4. $FeCl_{3(aq)} + NaOH_{(aq)} \rightarrow$
5. $H_2SO_{4(aq)} + NaOH_{(aq)} \rightarrow$
6. $KOH_{(aq)} + CuSO_{4(aq)} \rightarrow$

5. Combustion Reactions

- **Combustion reactions** occur when a hydrocarbon reacts with oxygen gas or metals.
- This is also called burning!!! In order to burn something you need the 3 things in the "fire triangle":
  1) A Fuel (hydrocarbon)
  2) Oxygen to burn it with
  3) Something to ignite the reaction (spark)



Combustion Reaction

$fuel + O_2 \rightarrow X_yO_z + energy$

A reaction of a fuel with oxygen, releasing energy in the form of heat and/or light

Combustion Reaction Examples:

- What is the main purpose for which fuels are burned around the world?
- The following equations show what happens when different carbon-based fuels are burned.
- $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} + energy$
- $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O + energy$
- ethanol $CH_3CH_2OH_{(l)} + O_{2(g)} \rightarrow CO_{2(g)} + 3H_2O_{(l)}$
- $C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(g)} + energy$

Combustion Reaction

Element + O_2 → "oxide" + energy

$2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$ + energy

$P_{4(s)} + 5O_{2(g)} \rightarrow P_4O_{10(g)}$ + energy

Combustion of other Fuels

Some fuels do not contain carbon.

The products are oxides of each element in the fuels.

- $Mg_{(s)} + O_{2(g)} \rightarrow MgO_{(s)}$
- $Cu_{(s)} + O_{2(g)} \rightarrow CuO_{(s)}$
- $H_{2(g)} + O_{2(g)} \rightarrow H_2O_{(l)}$
- $P_{4(s)} + 5O_{2(g)} \rightarrow P_4O_{10(g)}$
- $S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$

As you see, many combustion reactions may also be classified as synthesis.

Combustion Reactions

- **Combustion is a fast reaction of a substance with oxygen to make compounds called oxides.**
- **the general equation is :**

  fuel + oxygen → oxides + energy
- **the three things that must be present for combustion to happen are:**
  - **fuel**
  - **oxygen**
  - spark / heat

Combustion Reaction Examples:

- What is the main purpose for which fuels are burned around the world?
- The following equations show what happens when different carbon-based fuels are burned.
- $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ + energy
- $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O$ + energy
- ethanol $CH_3CH_2OH_{(l)} + O_{2(g)} \rightarrow CO_{2(g)} + 3H_2O_{(l)}$
- $C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(g)}$ + energy

Combustion of other Fuels

Some fuels do not contain carbon.

The products are oxides of each element in the fuels.

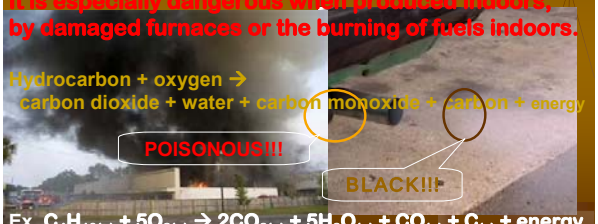
- $Mg_{(s)} + O_{2(g)} \rightarrow MgO_{(s)}$
- $Cu_{(s)} + O_{2(g)} \rightarrow CuO_{(s)}$
- $H_{2(g)} + O_{2(g)} \rightarrow H_2O_{(l)}$
- $P_{4(s)} + 5O_{2(g)} \rightarrow P_4O_{10(g)}$
- $S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$

As you see, many combustion reactions may also be classified as synthesis.

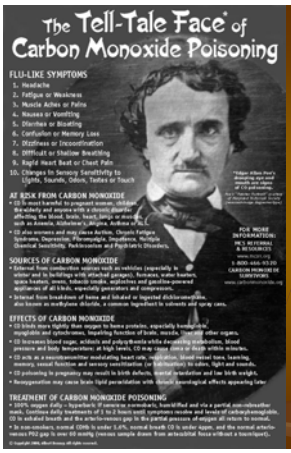
Incomplete Combustion

If there is not enough oxygen, then incomplete combustion occurs producing poisonous carbon monoxide gas (which is invisible and has no odor, colour or taste). It is especially dangerous when produced indoors, by damaged furnaces or the burning of fuels indoors.

Hydrocarbon + oxygen → carbon dioxide + water + carbon monoxide + carbon + energy



Ex. $C_4H_{10(g)} + 5O_{2(g)} \rightarrow 2CO_{2(g)} + 5H_2O_{(g)} + CO_{(g)} + C_{(s)}$ + energy



Combustion Reactions

Edgar Allen Poe's drooping eyes and mouth are potential signs of CO poisoning.

SUMMARY: An equation...

- **Describes a reaction**
- **Must be balanced in order to follow the Law of Conservation of Mass**
- **Can only be balanced by changing the coefficients.**
- **Has *special symbols* to indicate the physical state, if a catalyst or energy is required, etc.**

Mixed Practice

Identify the type of reaction for each of the following synthesis or decomposition reactions, and write the balanced equation:

$N_{2(g)} + O_{2(g)} \rightarrow$ Nitrogen monoxide

$BaCO_{3(s)} \rightarrow$

$Co_{(s)} + S_{(s)} \rightarrow$ (make Co be +3)

$NH_{3(g)} + H_2CO_{3(aq)} \rightarrow$

$NI_{3(s)} \rightarrow$

Mixed Practice #2

- State the type, predict the products, and balance the following reactions:

1. $BaCl_2 + H_2SO_4 \rightarrow$
2. $C_6H_{12} + O_2 \rightarrow$
3. $Zn + CuSO_4 \rightarrow$
4. $Cs + Br_2 \rightarrow$
5. $FeCO_3 \rightarrow$